Anti-Seismic Protection of Monumental Buildings

Protection contre les séismes des bâtiments et monuments

Erdbebensicherung von Monumentalbauten

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The poster-contribution refers to monumental buildings and particularly to churches of three-cusped plane wide-spread in the Carpatho-Danubian-Pontic area, where tectonic earthquakes frequently occur. The seismic response of these buildings mainly depends on their shapes. For the new buildings the anti-seismic protection consists in approaching the centers of mass and twist by using certain models of analysis. The decision of anti-seismic strengthening of the existing buildings is based on the map of damages, well drew up and correctly interpreted. The validity of the adopted solution is checked up by comparing the dynamic characteristics of monumental building, electronically measured, before and after strengthening.

La contribution-poster concerne surtout les bâtiments monumentaux et, en particulier, les églises à plan trilobé largement répandues dans la zone Carpato-Danubienne-Pontique, où les tremblements tectoniques surviennent fréquemment. La réponse sismique de ces bâtiments dépend principalement de leur configurations. Pour les nouveaux bâtiments la protection contre les séismes consiste dans le rapprochement des centres de masse et de torsion par l`utilisation certain modèles de calcul. Pour les bâtiments existents la décision de consolidation contre les séisme a pour base la carte des avaries, bien tracée et correctement interprétée. La validité de la solution adoptée est vérifiée par la comparaison des caractéristiques dynamiques du bâtiment, mesurées électroniquement, avant et après la consolidation.

Der Posterbeitrag bezieht sich im allgemeinen auf die Monumentalbauten und besonders auf die kleeblattformigen gebauten Kirchen, die in den pontischen, Donau- und Karpatengebieten sehr verbreitet sind und wo sehr häufig tektonische Erdbeben eintreten. Die seismische Antwort dieser Gebäude hängt grundsätzlich von ihrer Gestalt ab. Für die neuen Gebäude besteht der antiseismische Schutz aus dem Aneinanderrücken der Massen- und Drillungsmittelpunkte durch die Anwendung einiger einfachen Rechnungsmodelle. Bei den vorhandenen Gebäuden gründet sich die antiseismische Konsolidierungentscheidung auf die gut aufgezeichnete und genau interpretierte Beschädigungskarte. Die Gültigkeit der angenommenen Lösung wurde durch die Vergleichung der dynamischen Merkmale des Gebäudes untersucht, die sowohl vor als auch nach der Konsolidierung gemessen werden.

The oldest monumental buildings preserved in the Carpatho-Danubian-Pontic area are churches. For centuries they were the most representative creations of eccleastic and monumental architecture. Erected with stone or brick masonry these Eastern Churches of Balkan-Byzantine style were always an evidence of the level of technical knowledge and artistic refinement reached during their epoch. They also reflect the foreign influence on the autochthonous art of building.

Unfortunately, strong tectonic earthquakes frequently occur in this area.The main focus being located in the Carpathian curvature and at a depth of 150 km, it influences the whole area. The Eastern churches of three-cusped plane seeming to show an intrinsic sensitivity to earthquake actions. In the course of time some of them were completely destroyed. Others survived being, however, more or less, damaged. Often by strengthening parts of the original works were altered or even definitely sacrificed.

As concern the damages caused by earthquakes, first there should be mentioned the steeples. As a rule the masonry columns of the steeples are horizontally sheared at their bottoms and tops. The steeples of Wallachian churches yielded easier to shearing forces than those of Moldavian churches. Consequently, now in Bucharest, one churche out of three has false, wooden steeples.

Apse walls of the nave and altar are also severely damaged. The typical damages consist in vertical cracks when these curved or polygonal walls are completely closed, and in 45^{o} inclined cracks when there are e.g. openings for windows. The same two types of cracks have been developed in the straight walls of the ante-naves, especially when they were not braced at their tops.

The semi-circular arches as integral parts of the surrounding walls, designed to narrow the vaulted space and to support the cupola or steeple are also severely damaged by earthquakes. Generally, the cracks appear at the arch crown as well as at the quarter of the free spans. Such damages are often caused by ties mounted too eccentrically. A faulty foundation also allow damages to the apse walls and transverse arches. This is the case of churches rebuilt in a new masonry style over ancient foundations of wooden churches burnt or stone churches destroyed by seisms.

There are, however, churches of three-cusped plane which lasted for centuries without being damaged at all. It has been observed that in certain rather restricted areas churches of about the same size, being erected in the same period and with a comparable kind of foundations and brick-work behaved quite differently.The explanation seems to be in the variety of the adopted shapes.Therefore, it could be assumed that since long ago certain anti-seismic shapes were more or less conciously searched for. But no written rules or documents were preserved so far. Only the old Master`s Manole legend is going on as an ancient technical code.

The monumental buildings and particularly the churches have at least one axis of symmetry, and their seismic response depends mostly on their shapes. In the stage of design the anti-seismic shaping consists in balancing the buildings by approaching the centers of mass and twist. The structural solutions of anti-seismic strengthening consist in coating the walls, framing the openings and bracing the building body, but only after checking up, and if necessary improving, the foundations.